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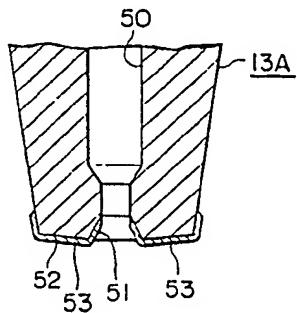
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(58) Field of search
B3R

(54) Method and apparatus for wire bonding

(57) A wire bonding apparatus, such as used frequently for assembling electronic parts, is designed to prevent a physicochemical reaction, which leads to defects in a wire bonding operation, from occurring between a bonding wire and a wire connecting tool so that fusion of the bonding wire to the wire connecting tool does not occur. The material of the connecting tool 13A is a substance which does not easily generate a physicochemical reaction with the bonding wire, and covering at least the region of the wire connecting tool 13A which contacts the bonding wire is a film 53 of a material which does not easily generate a physicochemical reaction with the bonding wire.

FIG. 9



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FIG. 2

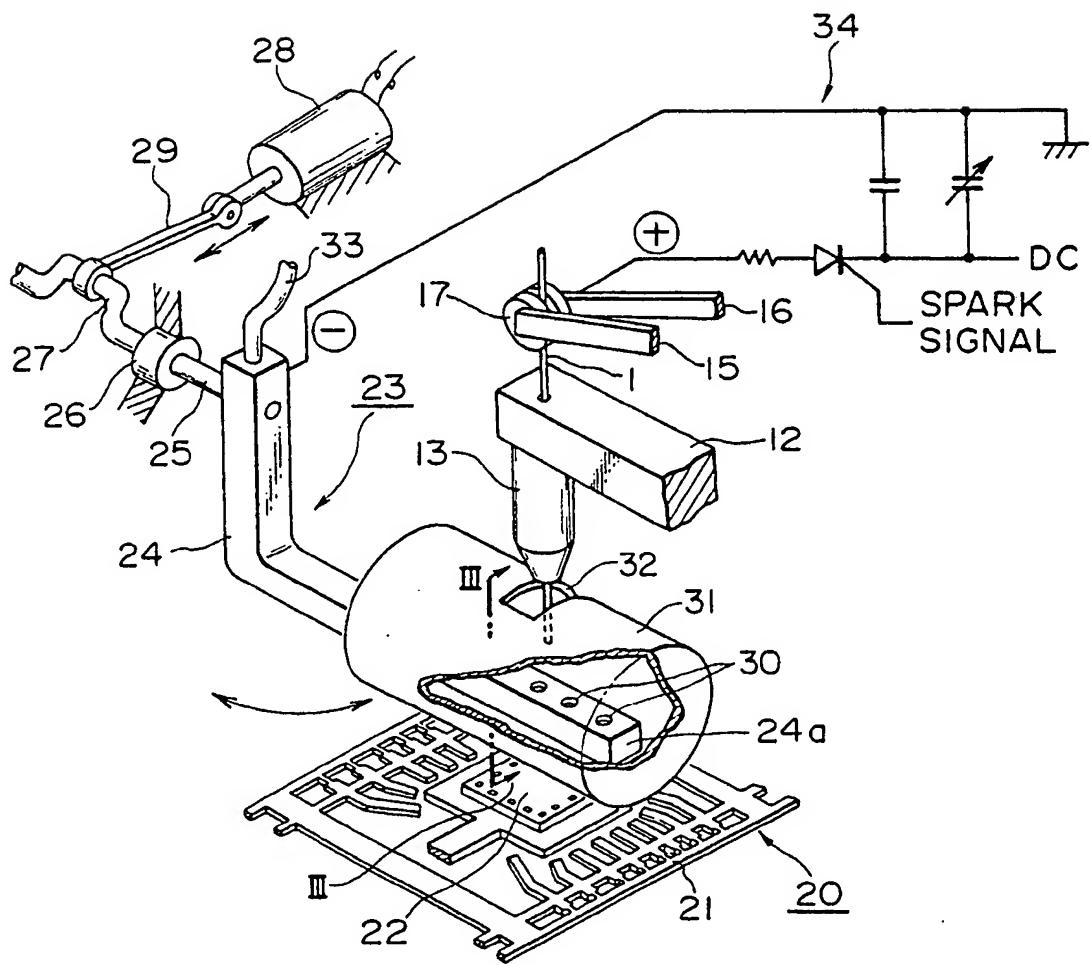


FIG. 3

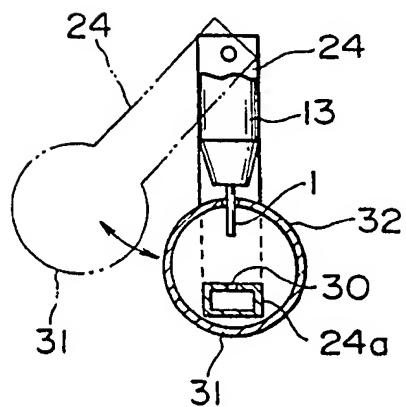
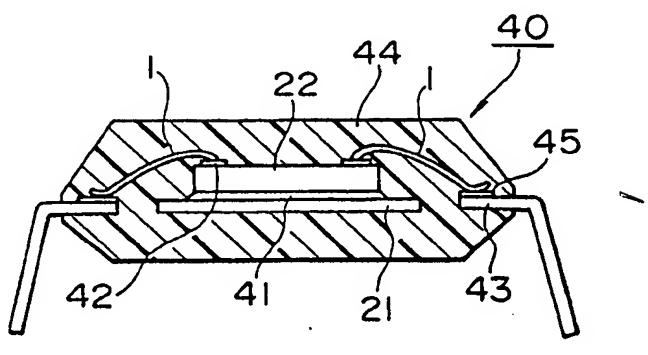


FIG. 4



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FIG. 9

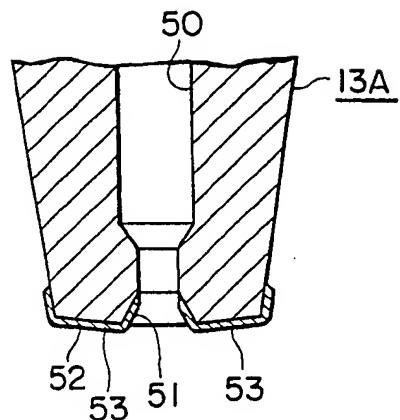


FIG. 10

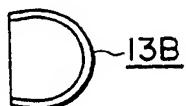


FIG. 11

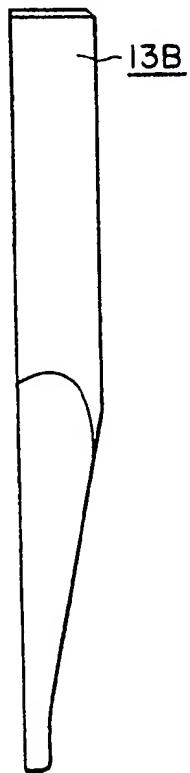


FIG. 12

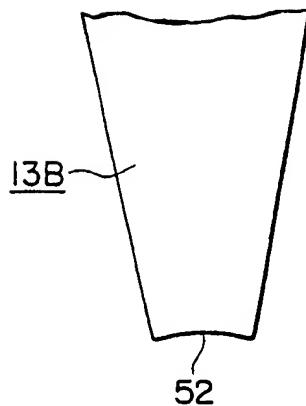
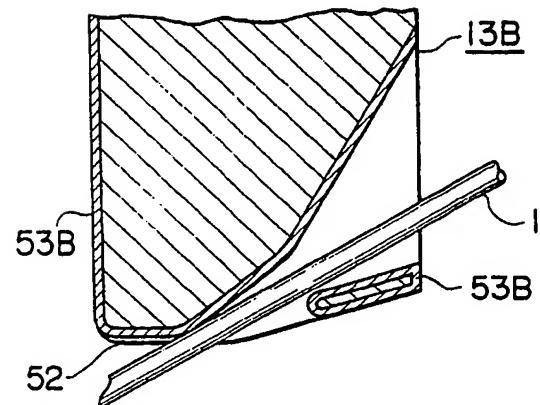


FIG. 13



TiC.

The alumina and ruby are the materials to which the aluminum Al sticks easily. The TiC-containing cermet is a material to which Al sticks only lightly. It has been ascertained that the extent to which Al sticks to a TiC-containing cermet varies depending upon the kind and content of the binder contained therein. It has been discovered that the causes from which Al sticks to a TiC-containing cermet reside in the following. It is considered that a conventional capillary consisting of a TiC-containing cermet contains not less than 25% by weight, which is based on the total weight of the capillary, of nickel (Ni) as a binder, and that the nickel (Ni) in the capillary generates a fusion reaction with Al which constitutes the Al bonding wire. Moreover, since the capillary consisting of a TiC-containing cermet is a sinter, it has a rough surface in which Ni constituting a binder is exposed, this Ni further promoting the fusion reaction between the Ni and Al wire.

An object of the present invention is to provide a wire bonding apparatus capable of preventing the fusion from occurring between a bonding wire and a wire connecting tool.

The present invention can provide a wire bonding apparatus capable of guiding freely with a wire connecting tool a bonding wire to a material to be wire bonded, and bonding the wire thereto with a high bondability.

The present invention can also provide a wire bonding method capable of bonding a wire to a material to be wire-bonded, by using a wire connecting tool with high accuracy and reliability.

The present invention can further provide a wire bonder capable of preventing the fusion of an Al wire and a capillary or a wedge to improve the bondability of the Al wire, and carrying out a wire bonding operation excellently without any insufficiently bonded portions.

Embodiments of the invention will be given in the following description in conjunction with the accompanying drawings.

Figure 1 is a front elevational view of an embodiment of a wire bonder according to the present invention;

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Figure 2 is an enlarged perspective view of a principal portion of the wire bonder shown in Figure 1;

Figure 3 is a sectional view take along the arrows III-III in Figure 2;

Figure 4 is a sectional view of a semiconductor device formed by carrying out a wire bonding operation with the wire bonder shown in Figure 1;

30 Figure 5 is a top plan view of an example of a capillary used in the present invention;

30

Figure 6 is a partially cutaway view in front elevation of the capillary shown in Figure 5;

Figure 7 is an enlarged sectional view of a tip portion of the capillary shown in Figure 6;

Figure 8 is a graph used to determine the content of nickel (Ni) used as a binder in the TiC cermet which constitutes a wire connecting tool;

35 Figure 9 is an enlarged sectional view of a tip portion of another example of a capillary used in the present invention;

35

Figure 10 is a top plan view of a wedge, still another example of the wire connecting tool used in the present invention;

Figure 11 is a front elevational view of the wedge shown in Figure 10;

40 Figure 12 is an enlarged left side elevational view of a tip portion of the wedge shown in Figure 11; and

40

Figure 13 is an enlarged sectional view of the tip portion of the wedge shown in Figure 11.

Figure 1 is a front elevational view of an embodiment of a wire bonder according to the present invention. Referring to Figure 1, a bonding arm 12 is supported pivotally at its base end on a bonding head 11 which is mounted on an XY table 10 placed on a base 100 of the wire bonder. Thus, a tip portion, to which a capillary 13, a wire connecting tool, is fixed, of the bonding arm 12 can be moved pivotally in the vertical direction by a cam mechanism. A pair of clasper arms 15, 16 actuated by a cam driving member 14 or an electromagnetic solenoid are provided above the bonding arm 12 so that the tip portions of these arms 15, 16 are positioned immediately above the capillary 13 to form a clasper 17. Reference numeral 1 denotes an Al wire used as a bonding wire. The Al wire is payed out from a spool 101 to be inserted through a guide 18 and then into the capillary 13 through the clasper 17. The wire is not limited to an Al wire; it may be a wire consisting of an easily oxidizable metal, such as aluminum alloys including aluminum containing a small amount of silicon (Si), and aluminum containing a small amount of nickel (Ni).

45

55 On the other hand, reference numeral 19 denotes a bonding stage, on which a lead frame 20 with a semiconductor element pellet, a material to be wire-bonded, bonded to the upper surface thereof, is placed. The Al wire 1 is connected between the lead frame 21 and semiconductor element pellet 22 as the capillary 13 is moved up and down.

50

60 Reference numeral 23 denotes a discharge electrode portion consisting of an electric conductor and provided independently in the proximity of the capillary 13. As shown in both Figure 2 and Figure 3, the discharge electrode portion 23 has a substantially L-shaped hollow electrode 24. A pivot 25 connected unitarily to an upper end portion of the electrode 24 is supported pivotably on a bearing 26 in a wire bonder fixing portion, as that the electrode 24 as a whole can be moved reciprocatingly in the horizontal direction, i.e. turned in the direction of a dual arrow in Figure 3. Accordingly, a lower portion 24a of the 65 electrode 24 can be moved below the capillary 13, i.e. between a positive immediately below the tip of

65

aluminium alloy material consisting principally of aluminium and containing about 1% by weight of silicon (Si) or an aluminium alloy consisting principally of aluminium and containing about 0.5% by weight of nickel (Ni) in place of the aluminium wire 1.

The capillary 13, i.e. the wire bonding apparatus (wire connecting tool) in the thermo-compression wire bonder is constructed as shown in Figure 5 which is a top plan view thereof, Figure 6 which is a partially cutaway view in front elevation thereof, and Figure 7 which is an enlarged section of the free end portion thereof. 5

The capillary 13 has as best seen from Figure 7 which illustrates the free end portion thereof on a larger scale conical chamfered portion 51 around the lower opening of an insert bore 50 for the Al wire 1, and an upper portion of the insert bore 50 which has an inner diameter slightly larger than that of the free end portion thereof. The free end surface 52 is not flat but inclined slightly toward its circumferential portion. The capillary 13 consists of a cermet composed mainly of titanium carbide (TiC) and containing an iron group metal as a binder. Since this cermet has a comparatively high processability, it is suitably used to manufacture a capillary having the above-mentioned complicated shape. As is clear from Table 10 in which the properties of TiC are compared with those of some other carbides, TiC has a low reactivity 15 with Al. The rating values shown in Table 1 were determined on the basis of the result of reactions between various kinds of carbides and a molten aluminium, which reactions were conducted by immersing these carbides in molten aluminium-containing vessels for 60 minutes. A larger rating value shows a higher reactivity of the carbide with Al. Moreover, TiC has sufficiently high strength which is required by 20 the capillary. 20

TABLE 1

25	Material	Reaction with Al	Rating value	25
30	TiC	Reacts a little.	2	
	ZrC	Reacts considerably.	4	
	Cr ₃ C ₂	Reacts actively.	5	
	Mo ₂ C	Reacts actively.	5	30
	WC	Reacts actively.	5	

A cermet is a heat-resisting material obtained by compression-molding a mixture of ceramic powder 35 and metal powder, and sintering the molded product. It was developed as a material having both the thermal resistance of a ceramic material and a high rigidity of a metal. The examples of the metal are Fe, Ni, Co, Cr and Cu, and the examples of the ceramic material are various oxides (Al₂O₃, BeO, ZrO₂ and ThO₂), carbides (TiC, ZrC, B₄C and WC) and borides (CrB and ZrB₂). The examples of combination of these materials include Al₂O₃-Fe, TiC-Ni, TiC-Co and B₄C-Fe. 35

On the other hand, nickel (Ni) is used effectively for the binder to be contained in TiC in a TiC cermet 40 as the material of the wire connecting tool. The inventors of the present invention varied the content (wt%) of this binder experimentarily to determine the advance of anyone else the characteristics shown in Figure 8 of the wire connection tool. The reaction rating values shown in Figure 8 are the same as those shown in Table 1. It is understood from Figure 8 that, when the content of nickel (Ni) is increased, 45 the strength of the wire connecting tool is improved with the possibility that the connecting wire reacts with (sticks to) Al, which constitutes a bonding wire, increasing, and that, conversely, when the content of nickel (Ni) in the capillary is reduced, the reactivity of the capillary with the Al wire as a bonding wire decreases with the mechanical strength of the capillary as a wire connecting tool decreasing. Therefore, the nickel content is set preferably to 5-20% by weight and optimal to 5-15% by weight in order to obtain 50 a capillary having a high mechanical strength and a low reactivity with respect to Al. In the experiments conducted by the inventors, some other kinds of binders containing molybdenum carbide (Mo₂C) were used. The results of various experiments show that the molybdenum carbide-containing binders having, for example, the following composition have excellent effects. The numeral values shown below represent weight percentages. 50

(1) TiC: Mo₂C : Ni = 70 : 15 : 15
 (2) TiC : Mo₂C : Ni = 60 : 20 : 20
 (3) TiC : Mo₂C : Ni = 76 : 12 : 12 55

Since the titanium carbide (TiC) and nickel (Ni) as a binder are not combined with each other directly, the molybdenum carbide is used as a mediator for combining the titanium carbide (TiC) with nickel (Ni). 60 Namely, the molybdenum carbide (Mo₂C) and titanium carbide (TiC) are combined with each other excellently, and the molybdenum carbide (Mo₂C) and nickel (Ni) are also combined with each other excellently. Therefore, molybdenum carbide (Mo₂C) is laid on titanium carbide (TiC) so that the surfaces of 65 particles of the latter are covered thoroughly with the former. Namely, the whole surfaces of the particles 65

state against a substrate, which is set to the negative electric potential, to form a film. In the hot cathode method, the vapor is not made in the form of cluster. In this method, the ion plating is done under high vacuum according to the principle which is substantially the same as that of the cluster ion beam evaporation.

5 The ion plating method has a good influence upon the crystallization of a film. It is considered that the reasons why the ion plating method is capable of obtaining a film having a high crystallinity are as follows. Due to the impact of the high-energy ions, the temperature of the surface of the substrate increases (to 100°C - 300°C). Due to the impact of the ions, many flaws occur on the substrate surface, and the crystallization proceeds therearound. The possibility of crystallization by the charge of ions is higher than
 10 that by neutral particles. Although the ions lose the electric charge before they impinge upon the substrate, they have high energy even after they enter the substrate. Accordingly, the ions can move easily in the surface of the substrate, so that crystals can be formed easily.

When the ion plating method is used, a film having a high bond strength can be formed at a temperature lower than that in the CVD method. Moreover, the particles of a material to be covered with a film
 15 are displaced favorably, so that a film can be formed in an excellent step covering manner on various types of objects including an object having a rough surface and an object having a complicated shape like a capillary and a wedge.

A SiN film or a TiC film can be formed on the free end portion of a capillary, a wire connecting tool used for a thermo-compression wire bonder, and a wedge, a wire connecting tool used for an ultrasonic
 20 wire bonder, at a lower temperature by the ion plating method than by the CVD method. Accordingly,
 25 when a film is formed by the ion plating method, no thermal deformation occurs in the wire connecting tool, so that a wire connecting tool having a high accuracy can be formed.

The various effects of the wire bonding apparatus according to the present invention may be understood clearly from the above statement. The present invention can have further effects which are as follows.

(1) The wire connecting tool may consist of a capillary is made of titanium carbide (TiC) containing 5 - 15% by weight of nickel (Ni) as a binder. Accordingly, the wire connecting tool consisting of a capillary can secure its required level of strength, and has a reduced reactivity with respect to an Al wire. Therefore, the sticking of an Al wire to the wire connecting tool consisting of a capillary can be prevented, and
 30 the bondability of the wire bonding apparatus can be improved, so that an insufficient wire bonding operation can be virtually prevented.

(2) A SiN film or a TiC film can be formed on the surface of the wire connecting tool consisting of a capillary composed mainly of TiC. Owing to the low reactivity of the film material with respect to the aluminium (Al) wire, which is used as a bonding wire, and the smooth surface of the film, the sticking of
 35 the Al wire to the wire connecting tool can be prevented more effectively.

(3) A film, such as a TiC film, which does not generate a physicochemical reaction with aluminium (Al), may be formed on at least the portion of a capillary, a wire connecting tool used in the thermo-compression wire bonding, or a wedge, a wire connecting tool used in the ultrasonic wire bonding, which contacts a bonding wire. Accordingly, the aluminium (Al) wire used as a bonding wire does not stick, when
 40 it is fused, to the wire connecting tool provided with such a bonding wire sticking-preventing film thereon. Therefore, the aluminium (Al) wire, which is guided by the wire connecting tool to be bonded to an object material, does not cause any decreased in the bondability of the wire bonding apparatus in
 45 operation, so that a wire bonding operation can be carried out with a high accuracy and a high reliability.

The preferable examples of the material for the bonding wire sticking-preventing film are silicon nitride (SiN), titanium carbide (TiC), zirconium carbide (ZrC), carbides of the elements in IV group in the Periodic Table, or carbides of the elements in V group therein, or carbides of the elements in VI group therein and nitrides, such as boron nitride (BN).

The specially effective methods of forming such a film are the chemical vapor deposition (CVD) method, and the ion plating method which is capable of forming the film at which a temperature lower
 50 than the temperature at which the CVD method is carried out. However, the film can also be formed by using various other film-forming techniques.

The capillary body or the wedge body, which constitutes a wire connecting tool on which the film is to be formed, can be molded out of tungsten carbide (WC), tantalum carbide (TaC), titanium carbide (TiC), alumina, single crystal of sapphire, and ruby, i.e. molten alumina. The wire connecting tools consisting of
 55 these materials and having various shapes can be used.

(4) A wire bonding apparatus using a wire connecting tool according to the present invention is capable of feeding a bonding wire smoothly without being stuck to the wire connecting tool, during a wire bonding operation in a semiconductor device assembling step. Accordingly, the wire bonding can be done normally. Namely, the wire bonding can be done without hurting a member to be wire-bonded,
 60 without causing an unsatisfactorily wire-bonded semiconductor device to be produced, and with a high accuracy, a high reliability and a high work efficiency.

(5) In the wire bonding method using the wire connecting tool according to the present invention, the bonding wire is not fused to the wire bonding tool. Therefore, the wire connecting tool is not stopped up with the bonding wire. Namely, the bonding wire is fed normally. As a result, a wire bonding operation
 65 under an abnormal pressure can be avoided. Moreover, the wire bonding can be done with a suitable

lary for carrying out a thermo-compression wire bonding operation with the ultrasonic oscillation applied thereto, said capillary being provided with a through bore extending in the axial direction thereof and adapted to insert said bonding wire therethrough.

13. A wire bonding tool according to claim 9 or claim 10 wherein said wire connecting tool is a wedge for carrying out an ultrasonic wire bonding operation. 5

14. A wire bonding tool according to any one of claims 9 to 13 wherein said wire connecting tool is molded out of a cermet of titanium carbide (TiC) containing 5 - 15% by weight of nickel (Ni) as a binder. 10

15. A wire bonding tool according to any one of claims 9 to 13 wherein a body of said wire connecting tool is molded out of a cermet of titanium carbide (TiC) containing 5 - 15% by weight of nickel (Ni) as a binder, at least the region of said wire connecting tool body which contacts said bonding wire is covered with a film consisting of a material which does not easily cause said bonding wire to react physico-chemically with the surface of said wire connecting tool. 10

16. A wire bonding tool according to any one of claims 9 to 13 wherein said wire connecting tool is covered at at least the region of a body thereof which contacts said bonding wire with a film consisting of a material which does not easily cause said bonding wire to react physicochemically with the surface of said wire connecting tool. 15

17. A wire bonding tool according to any one of claims 9 to 13 wherein said wire connecting tool is covered at at least the region of a body thereof which contacts said bonding wire with a film consisting of a carbide or a nitride of an element in IV group, V group and VI group in the Periodic Table, such as titanium carbide (TiC), tantalum carbide (TaC), zirconium carbide (ZrC), silicon nitride (SiN) and boron nitride (BN), said film being formed by the chemical vapor deposition method or the ion plating method. 20

18. A wire bonding tool according to Claim 17, wherein the thickness of said film formed on said wire connecting tool is 0.1 - 10 µm. 25

19. A wire bonding tool according to claim 17 or claim 18 wherein the material of said wire connecting tool body is a material consisting mainly of titanium carbide (TiC) or tungsten carbide (WC) or tantalum carbide (TaC), or alumina ceramic, sapphire or ruby. 25

20. A wire bonding tool according to Claim 9, wherein a body of said wire connecting tool consists of one of titanium carbide (TiC) cermet, tungsten carbide (WC) cermet, tantalum carbide (TaC) cermet, alumina ceramic, sapphire and ruby, said film, with which at least the region of said wire connecting tool body which contacts a wire used as said bonding wire and consisting mainly of aluminium (Al) is covered, being composed of one of titanium carbide (TiC), tantalum carbide (TaC), zirconium carbide (ZrC), silicon nitride (SiN) and boron nitride (BN) and formed by the chemical vapor deposition method or the ion plating method. 30

21. A method of wire bonding substantially as any herein described with reference to the accompanying drawings. 35

22. A wire bonding tool substantially as any herein described with reference to and as shown in the accompanying drawings. 35